A Framework for Critical Infrastructure Resilience Analysis

Sandia is working with the Department of Homeland Security to optimize infrastructure recovery strategies in the wake of natural disasters

The federal government's traditional policy toward critical infrastructure security is one of physical protection and "hardening" of infrastructure assets (e.g., electricity, water supply). In recent years, the Department of Homeland Security (DHS) has recognized that "protection, in isolation, is a brittle strategy," and that critical infrastructure protection policies should consider not only the prevention of disruptive events, but also the processes that infrastructure systems undergo to maintain functionality following disruptions. This more comprehensive approach has been termed critical infrastructure resilience and has become a top-level strategic objective for DHS. In support of this objective, Sandia has formulated a unique assessment framework for evaluating the resilience of critical infrastructure and economic systems. This framework is the first of its kind that is flexible enough to consider all types of critical infrastructure systems while explicitly evaluating resources and costs of recovery.

The framework, illustrated in Figure 1, is composed of three primary components:

1. A newly formulated definition of system resilience that focuses on the system components that need to be considered for a resilience assessment;
2. A ***quantitative*** methodology for measuring system resilience; and
3. A ***qualitative*** methodology that can be used in place of, or to explain, quantitative results.

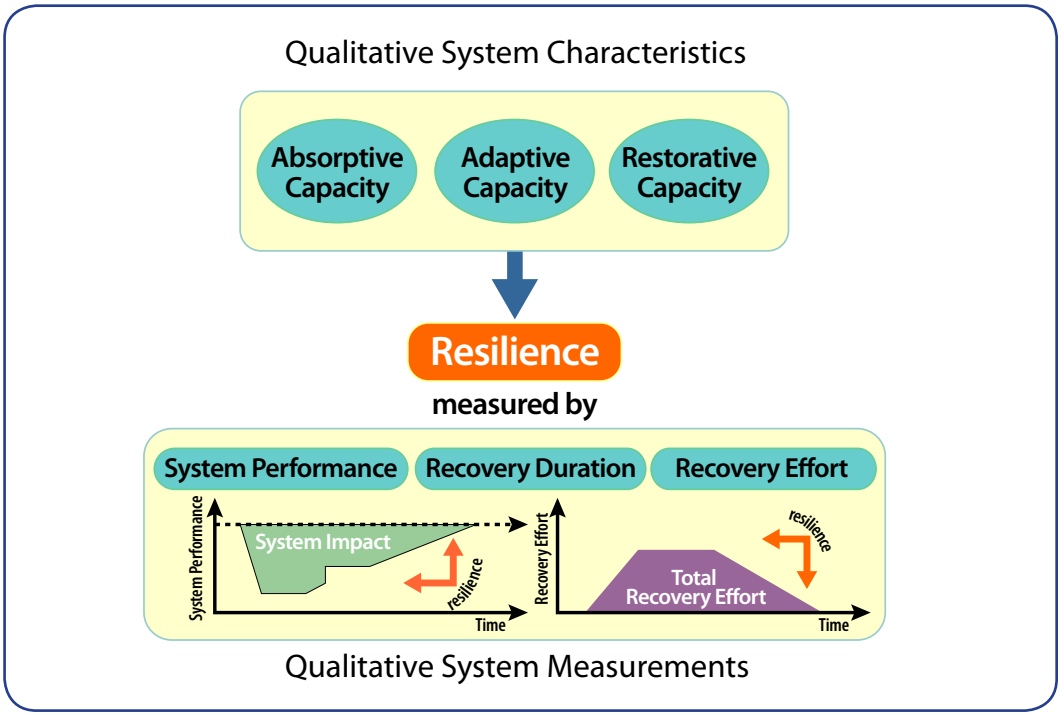

Figure 1: Sandia's resilience assessment framework combines qualitative system evaluations with quantitative measurements to provide a comprehensive resilience analysis, as shown in this conceptual rendering.

For more information:

Technical Contact:
Lillian Snyder
505-284-3378
lasnyde@sandia.gov

Science Matters Contact:
Alan Burns
505-844-9642
aburns@sandia.gov

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The ***quantitative*** measurement methodology is founded in the mathematics of optimal control theory and evaluates both disruption impacts to infrastructure system performance and how resources are allocated to recover from a disruption. This portion of the resilience assessment framework can be used to select dynamic recovery strategies that enhance infrastructure resilience. Sandia is currently researching how the application of optimal control techniques can be used to develop optimal recovery strategies that maximize resilience and that may not have been previously identified by infrastructure system managers.

The ***qualitative*** methodology provides the analyst with a structured process for reviewing system features and structures that enhance or impede infrastructure resilience. Key system components are assigned to one of three resilience capacity categories: absorptive, adaptive, and restorative. This categorization provides the analyst insight into how the infrastructure system copes with a disruptive event by absorbing the initial impacts from the disruption, internally reorganizing and adapting to new system conditions, and/or receiving external assistance in recovering from the disruption and restoring functionality. The analyst can then use this insight to assess how to enhance infrastructure resilience. Together, the qualitative and quantitative components of the framework provide a comprehensive view of the resilience of the system along with the means for enhancing its resilience.

This framework has been used to assist DHS in preparing for large-scale disruptions to national critical infrastructure systems. The qualitative methodology has been implemented to assess the resilience of infrastructure systems in the Southern and Midwestern United States to a large earthquake in the New Madrid Seismic Zone. The entire framework is currently being applied to a set of chemical supply chains, with the goal of assessing the resilience of these supply chains to a number of natural and manmade disruption scenarios.

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